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Injury Risk Assessment of Single Target and Area Fire Less Lethal Munitions

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ABSTRACT

In the midst of downsizing and budget cuts, the United States Military faces the difficult task of remaining an elite lethal fighting unit while acting as a global police force. In places like Haiti, Somalia, and now Bosnia, the U.S. forces must engage a different type of combatant; unarmed men, women, and children. In order to deal with these types of conflict, the military has turned its focus to non-lethal alternatives. One of these alternatives is specialty impact munitions or kinetic energy rounds. Since each munition is designed for a specific application, a common method of determining a risk of injury related to blunt trauma has to be established. Since these rounds are designed not to penetrate the body, the most applicable means of assessing the potential injury is to determine the severity of blunt trauma. Tests were conducted on the 3-Rib Chest Structure (3-RCS) with an injury criterion developed within the automotive industry to assess blunt thoracic impacts. This criterion called the Viscous Criterion (VC) is dependent on not only the amount of chest deflection but also the rate at which it occurs. These are the two basic components contributing to the severity of injury associated with blunt trauma. The purpose of this study was to evaluate a risk of injury from non-lethal projectiles utilized by the military and law enforcement communities.

INTRODUCTION

The need to control potentially damaging or life threatening situations without the use of lethal force poses a unique challenge to those in authority. A gathering of a large crowd, whether celebrating or protesting, can become a threat to the safety of those involved. In addition to the need to control large crowds, law enforcement officials have also been confronted with individuals that pose a threat to themselves or others. These scenarios often do not warrant the use of lethal force. Therefore, the ballistics industry, as well as the military, has researched and developed products which are often called non-lethal or less-lethal. These products include such devices as chemical irritants, distraction devices and kinetic energy projectiles. In the past several years, the types of less-lethal projectiles, as well as their application, has steadily increased. However, a standard testing method to determine their effectiveness and associated risk of injury has not been developed. One proposed method is presented to assess the trauma associated with blunt impacts to the thoracic region caused by less lethal projectiles.

BACKGROUND

In the midst of downsizing and budget cuts, the United States Military faces the difficult task of remaining an elite lethal fighting unit while acting as a global police force. In conflicts such as the Persian Gulf, the military is called upon to use superior technology to liberate a country under siege. More recently however, the military has been called upon to free individuals from civil unrest, offer famine relief, and keep warring factions apart. In places like Haiti, Somalia, and now Bosnia, the U.S. forces must engage a different type of combatant; unarmed men, women, and children.

In order to deal with these types of conflict, the military has turned its focus to non-lethal alternatives. One of these alternatives is specialty impact munitions or kinetic energy rounds. These munitions include rubber pellets, wood batons, rubber sabots, foam batons, and bean bags. Each munition has a specific application determined by the "knock-down" effectiveness and accuracy of each round. These munitions are not intended to take the place of lethal weapons, but rather offer an alternative prior to the use of lethal force. These munitions defuse aggressive or threatening actions, either through individual blunt force or by promoting area denial.

There are two basic categories of specialty impact munitions available in the 12 gauge or 40 mm weapon systems; single projectile and multiple projectiles. Single projectiles allow the shooter to isolate single targets, such as a "ring-leader" or instigator and generally deliver a greater impact force. The munitions available in the 12 gauge weapon system include the bean bag, fin sabot, single ball, and wood baton. A single bean bag round can be fired out of the M79 or M203 grenade launchers within the 40 mm systems. Multiple projectile munitions, also referred to as area denial munitions, are used for multiple targets such as a crowd line or to promote area denial. Because these munitions contain several projectiles and are less discriminate in their target, they generally deliver a lower impact force. Types of these munitions include rubber pellets shot at two velocities from the 12 gauge and multiple pellets or balls, foam batons, and wood batons shot from the 40 mm weapon systems.

Although varying in the desired effects, the common objective of these munitions is to exert enough force to ensure compliance. In order to maintain a non-lethal outcome, it is necessary to minimize this force. This must be done without jeopardizing the safety of the soldiers and that of the combatants. To obtain this goal, these munitions will have an inherent potential for causing injury, but with a low probability of causing serious physical harm. The impact of the projectile, along with the associated pain, work together to deter the individual from the unwanted aggressive action. Because of the dynamics of how these munitions function, a method of determining a threshold of blunt injury needs to be established.

One industry where the incidence and consequence of blunt thoracic trauma has been extensively investigated is the automotive industry (1,2). In a set of papers authored by Kroell (4,5), the amount of compression was investigated as a means for assessing blunt thoracic chest injuries. Kroell demonstrated that rib fractures occurred when a 20% compression was induced by a impact velocity of 5-7 m/s. When the compression reached 40% multiple rib fractures occurred in the cadavers tested. This level of compression was associated with a 50-50 chance of sustaining severe chest injury (2).

In 1985 Viano and Lau (6) developed a new criterion called the Viscous Criterion (VC). The VC has been documented to predict the severity of soft tissue injury and cardio-respiratory dysfunction caused by blunt impacts (2). It is a time dependent product of the velocity of the deformation of the chest (V) and the amount compression (C) (6). The chest compression is defined as the displacement of the chest in relationship to the spine normalized by the initial thickness of the thorax. Thus, this criterion is dependent upon not only the amount of compression, but also the rate at which the compression occurs. As discussed by Kroell et al. (7), both compression and velocity of compression contribute to the severity of injury related to chest impacts. They have also demonstrated that VC is a good predictor of functional injury to the heart

and respiratory system. This functional injury was demonstrated in the form of cardiac arrhythmias.

Studies have also shown (2, 6, 8) that VC is the best indicator for injuries of soft tissues for deformation velocities between 3 and 30 m/s. When the deformation velocity is below 3 m/s , the impact velocity becomes less critical. At these lower velocities, the mechanism of injury is one of a crushing of tissues. When the deformation velocity reaches above 30 m/s, the compression of the tissue becomes insignificant because the mechanism of injury is one of a blast injury.

In an effort to determine the effects of a given impact a biomechanical surrogate is employed. Developed and validated against existing human response data, biomechanical surrogates are commonly called crash test dummies. Instrumentation strategically placed within the surrogate allows for essential data to be coll ted from which the VC and related risk of injury can be calculated. Current surrogates include the Hybrid III for frontal impacts and the BIOSID and EuroSID for lateral impacts.

Recently, a new frontal impact surrogate has been developed known as the 3-Rib Chest Structure (3-RCS). This system was developed because of the need for a portable, low cost system that can be utilized outside of the automotive industry. The field of non-lethal or less-lethal ballistics is one area where this system can be utilized to provide injury data. Utilizing the ribs of the BIOSID, the 3-RCS is designed for the collection of data with low mass, high velocity impacts. Preliminary data was collected to investigate the effectiveness of several different types of non-lethal or less-lethal projectiles utilizing the new 3-RCS.

STUDY DESIGN

Testing was conducted at the Washtenaw Community College (Ypsilanti, MI) firing range. The three-rib structure was placed on a movable chart at the far end of the range at height that allowed for impacts to occur at the center of the sternum. The projectiles were fired from either a 12 gauge shotgun or a 37 mm gas gun at 30 and/or 45 feet based on the specifications of the munitions being tested. The velocities of these projectiles were recorded with an Oehler Research, Inc. Model 35P chronograph placed approximately 20 feet from the desired point of impact.

Several munitions were tested that were considered non-lethal or less-lethal. The basic design of the munitions is similar to that of lethal projectiles. There is a primer at the distal end followed by a propellant charge. Next, varying submunitions are placed between a lower and upper wad. The entire munition is encased in an outer shell. The main difference between lethal and less-lethal munitions is the design of the submunition and amount of propellant. These two variables helped to determine the velocity, range, and impact characteristics of the munitions.

The types of submunitions varied from a single, larger projectile like a bean bag to several smaller projectiles such as rubber balls. The variance in the design of the submunition allowed for the variance in the scenarios for which they were to be utilized; i.e. a single target or area fire. The proximity of the scenario also is a contributing factor as to which munition would be most

effective. Given this reason, the munitions were tested at the two distances of 30 or 45 feet. Some of the munitions were tested at both when their application allowed.

In addition to the velocity of the projectile, the location of each impact was recorded. The three-rib system has a 6" X 9" impact surface made of Ensolite® padding that was 5/8 inch thick and had a known density of 9-10 pounds per cubic foot. The padding was replaced at the beginning of the testing of each new munition. The 6 inch by 9 inch pad was divided into the 9 regions indicated below:

UL	UC	UR
ML	C	MR
LL	LC	LR

During this testing it was felt that the accuracy of the rib deflection is dependent upon where the impact occurred. The center impacts were considered to be the most accurate with a decrease in accuracy occurring as the impacts approached the exterior. Testing conducted at a later date utilizing high speed video confirmed this theory.

One channel of data from the three-rib system was collected by RC Electronics data acquisition system via an A to D board. This input was received from the linear transducer located behind the sternum at the level of the middle rib. This measurement provided the amount displacement as a function of time that occurred within the thoracic. From this measurement, the VC was calculated.

RESULTS/DISCUSSION

The results varied depending upon the type of munitions. Those munitions designed to be utilized for area fire, multiple balls and foam or wood batons, had several smaller projectiles as submunition within their casing. Once fired, these submunitions were designed to disperse outward. Therefore, the amount of kinetic energy each one contained was minimal and was not adequate to cause any rib deflection even if several impacted the target at the same time. Therefore, VC values were not calculated for these munitions.

Refinement of the testing process occurred based on more recent testing where high speed video was also incorporated. The area of shot placement and velocity of chest deflection was utilized as a guideline of acceptance. If an impact occur outside of the 2" X 3" rectangular area surrounding the center it was not considered to be accurate. Additionally, if the chest deflection exceeded 10m/s than the test was also disregarded since this value exceeded the specifications of the transducer.

Those impacts that were considered accurate based on the above criteria were then analyzed. The results of this analysis are presented below:

PROJECTILE TYPE	MASS (gm)	IMPACT VELOCITY (m/s)	CHEST DISPLACEMENT (mm)	IMPACT ENERGY (J)	VC
.60 cal rubber ball	3.7	346	5.00	221.41	.09
.60 cal rubber ball	3.7	326	7.58	197.14	.20
12 ga bean bag	41	94	10.90	180.67	.28
12 ga bean bag	41	92	9.50	174.85	.24
12 ga bean bag	41	98	12.06	195.02	.19
40mm bean bag	100	66	12.70	216.72	.20

Applying the Viscous Criterion to previously published blunt frontal impact data, statistical analysis show that the VC max was highly correlated with the risk of severe injury. There is a very low probability of injury for corresponding low values of VC. Accordingly, with very high values of VC, the probability of injury is essentially 100%. There is a transition zone between these two regions where the probability of injury is proportional to a change in VC (9). The compression criterion indicates that the highest risk of injury occurs at the point of maximum deflection. However, the VC indicates that the highest risk of functional injury occurs at approximately the midpoint, well before the maximum deflection is reached. Because of this, recommended values of viscous tolerance for the chest of VC max are 1.00 m/s and a compression tolerance of 35% (10).

CONCLUSION

Injury due to chest impact is primarily related to the amount of energy absorbed. The viscous response relates to the energy absorbed by rate-dependent processes; the higher the VC, the greater the energy absorbed by the tissue and the greater the risk of injury. Typically, lightweight projectile impacts result in minimal energy transfer to whole body motion. However, understanding the relationship between energy transferred to chest deformation and whole-body motion is a critical factor in comparing experimental results (11). Several theories were explored, including the possibility that the lower ballistic mass transfers less energy to rib deflection and more to accelerating the mass of the chest. However, the exact mechanism for these results remains unclear.

Based on this modeling and on previous research, the ballistics do not appear to be in the range where fatality occurs, which is consistent with actual field use of this munition. However, there are a few limitations that exist with this analysis. The small sample size for the ballistic testing becomes a concern when there is a desire to generalize the results. Further testing has recently been completed and initial findings are consistent with these indications. However, this is not to say that serious injury or death could not result with an impact of less lethal projectiles. In order to minimize this risk of injury, it is essential that these munitions be deployed in a proper manner.

REFERENCES

1. Cavanaugh, JM The biomechanics of thoracic trauma. Accidental Injury: Biomechanics and Prevention. Eds. Nahum, A.M. and Melvin, J.M. Springer-Verlag: New York (1993).

2. Lau IV and Viano DC The Viscous Criterion - Bases and Applications of an Injury Severity Index for Soft Tissue. SAE 861882, Stapp Crash Car Conference. SAE (1986).

3. Patrick LM, Kroell CK, Mertz HJ. Forces on the human body in simulated crashes. Proc Ninth Stapp Car Crash Conference. University of Minnesota, pp 237-260, 1965.

4. Kroell CK, Schneider DC, Nahum AM. Impact tolerance and response of the human thorax. 15th Stapp Car Crash Conference SAE (1971).

5. Kroell CK, Schneider DC, Nahum AM. Impact tolerance and response of the human thorax II. 18th Stapp Car Crash Conference SAE (1974).

6. Viano DC and Lau IV. Thoracic Impact: a viscous tolerance criterion. Tenth International Conference on Experimental Safety Vehicles. Oxford, England. pp. 104-114, 1985.

7. Kroell CK, Allen SD, Warner CY, Perl TR Interrelationship of velocity and chest compression in blunt thoracic impact to swine II. SAE 861881. Stapp Crash Car Conference. (1986).

8. Lau IV and Viano DC. Influence of Impact Velocity and Chest Compression on Experimental Pulmonary Injury Severity in an Animal Model. J Trauma 21: 1022-1028, 1981.

9. Viano DC. General Motors Research Laboratories. Live Fire Testing: Assessing Blunt Impact and Acceleration Injury Vulnerabilities. (GMR-6690). Warren, Michigan. (1989).

10. General Motors Research Laboratories. SEARCH: GMR's Viscous Criterion Impacts Safety Research. (Vol. 26, No.2). Warren, Michigan. (1991).

11. Viano DC, Andrzejak DV, Polley TZ, and King AI. Biomechanics of Fatal Baseball Impact of the Chest in Children. The American Society of Mechanical Engineers. 126: 95-103, 1992.